How You Can Assess Engineering Controls for Tuberculosis In Your Health Care Facility

Developed by: Francis J. Curry National Tuberculosis Center
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National Center for HIV, STD, and TB Prevention
Centers for Disease Control and Prevention

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U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Services

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How You Can Assess Engineering Controls for Tuberculosis in Your Healthcare Facility

You Don't Need a Weatherman to Know Which Way the Wind Blows

CONTENTS

I. Learning Objectives

How You Can Assess Engineering Controls for Tuberculosis in Your Healthcare Facility

You Don't Need a Weatherman to Know Which Way the Wind Blows

Learning Objectives

After watching this video and reading the accompanying materials, viewers will be able to:

1) Identify recommended engineering controls for isolation, sputum induction and waiting rooms

2) Calculate air change rates based on room volume and room exhaust airflow rate

3) Discuss how to select, use and place HEPA filter units

4) Describe how to verify negative pressure for isolation rooms

5) Demonstrate how to use room pressure monitors

6) Estimate room clearance times

II. Text and Diagrams from the Video

Please note that this section contains some additional slides that were not included in the video.

How You Can Assess Engineering Controls for Tuberculosis in Your Healthcare Facility

You Don't Need a Weatherman to Know Which Way the Wind Blows

1. Isolation Rooms
2. Ventilation
3. Exhaust Air
4. HEPA Filter Units
5. Negative Pressure Verification
6. Negative Pressure: How Much?
7. Room Pressure Monitor
8. Room Clearance Time
9. Sputum Induction
10. Waiting Rooms

How You Can Assess Engineering Controls for Tuberculosis in Your Healthcare Facility

Staff Responsible for TB Control

- Infection Control Coordinators
- Safety Officers
- Employee Health Practitioners
- Facility Engineers

1. Isolation Rooms

Recommendations for Isolation Rooms

- Ventilation rate of at least 12 ACH
- Negative pressure room
- Exhaust air from room to outdoors or HEPA-filtered

2. Ventilation

Where does the 12 ACH recommendation come from?

- CDC recommends 12 ACH in isolation rooms for:
  - new construction
  - renovation
  - where HEPA filters units are used
- 12 ACH readily achievable with supplemental HEPA filter units
- 12 ACH meets all local requirements known to ICS

But doesn't the CDC recommend 6 ACH for isolation rooms?

- CDC allows 6 ACH for "existing" rooms:
  - "based on comfort- and odor-control considerations"
  - higher ventilation rates "are likely to produce an incrementally greater reduction in the concentration of bacteria"
  - increase to 12 ACH "where feasible"
- 6 ACH may not satisfy local requirements, even for existing rooms

2. Ventilation (continued)

Calculate Ventilation Rate

Step 1: Calculate room volume

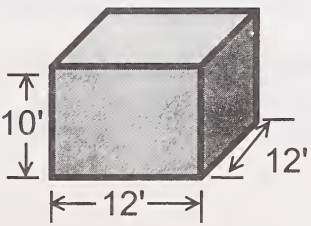
room volume =

room length x room width x room height

Calculate Ventilation Rate

Example: Calculate room volume

Room is 12 ft. long by 12 ft. wide with a ceiling height of 10 ft.



2. Ventilation (continued)

Calculate Ventilation Rate

Example: Room volume calculation

room volume =

12 ft. long **x** 12 ft. wide **x** 10 ft. high

room volume = 1440 cubic feet (ft^3)

Calculate Ventilation Rate

Step 2: Calculate exhaust airflow rate in ft^3 of air per hour

- Measure exhaust airflow rate in cubic feet per minute (CFM)
- Multiply by 60 minutes to find the exhaust air flow rate per hour

Calculate Ventilation Rate

Example: Calculate exhaust airflow rate in ft^3 of air per hour

- Flow hood measures 180 cubic feet per minute (CFM)

Calculate Ventilation Rate

Example: Calculate exhaust airflow rate in ft^3 of air per hour

Hourly exhaust airflow rate

= 180 CFM x 60 minutes

= 10,800 cubic feet per hour

Calculate Ventilation Rate

Step 3: Calculate air changes per hour (ACH)

$$ACH = \frac{\text{exhaust air flow per hour (}\textbf{\textit{from Step 2}}\text{)}}{\text{room volume (}\textbf{\textit{from Step 1}}\text{)}}$$

Calculate Ventilation Rate

Example: Calculate air changes per hour (ACH)

$$ACH = \frac{10{,}800 \text{ cubic feet per hour}}{1440 \text{ ft}^3}$$

$$= 7.5 \text{ ACH}$$

2. Ventilation (continued)

Calculate Ventilation Rate

additional CFM = total CFM req'd. — measured CFM

Calculate Ventilation Rate

Step 4: Calculate additional CFM required

Total CFM req'd. =

$$\text{room volume} \times \frac{12 \text{ ACH}}{60 \text{ minutes}}$$

2. Ventilation (continued)

Calculate Ventilation Rate

Example: Calculate additional CFM required

$$\text{total CFM} = 1440\ \text{ft}^3 \times \frac{12\ \text{ACH}}{60\ \text{minutes}}$$

$$= 290\ \text{CFM}$$

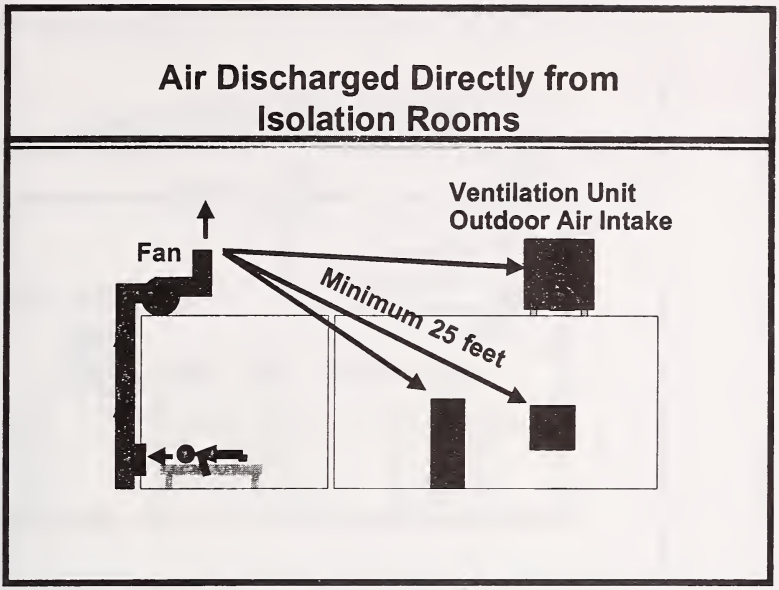
Calculate Ventilation Rate

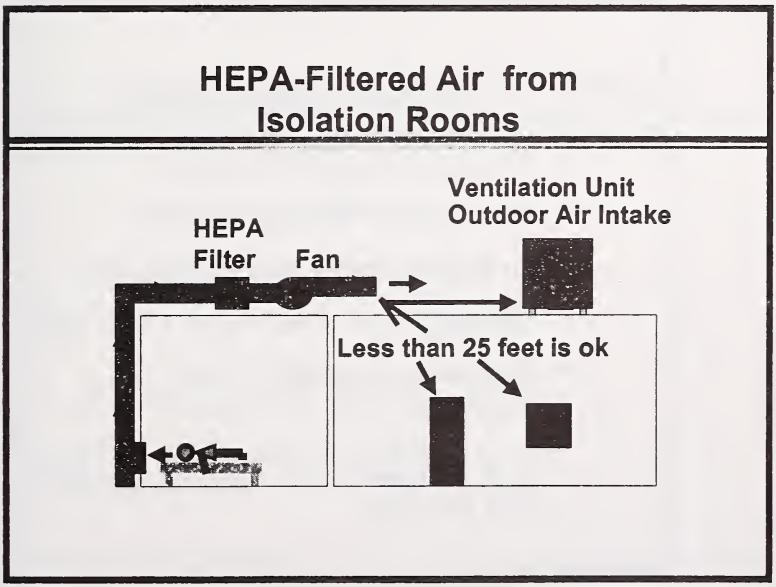
Example: Calculate additional CFM required

$$\text{additional CFM} = 290\ \text{CFM} - 180\ \text{CFM}$$

$$= 110\ \text{CFM}$$

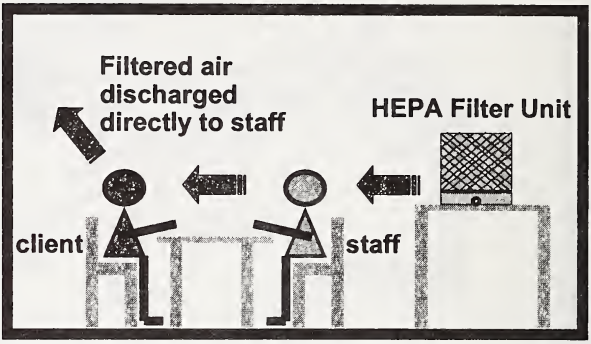
3. Exhaust Air





4. HEPA Filter Units

HEPA Unit Location

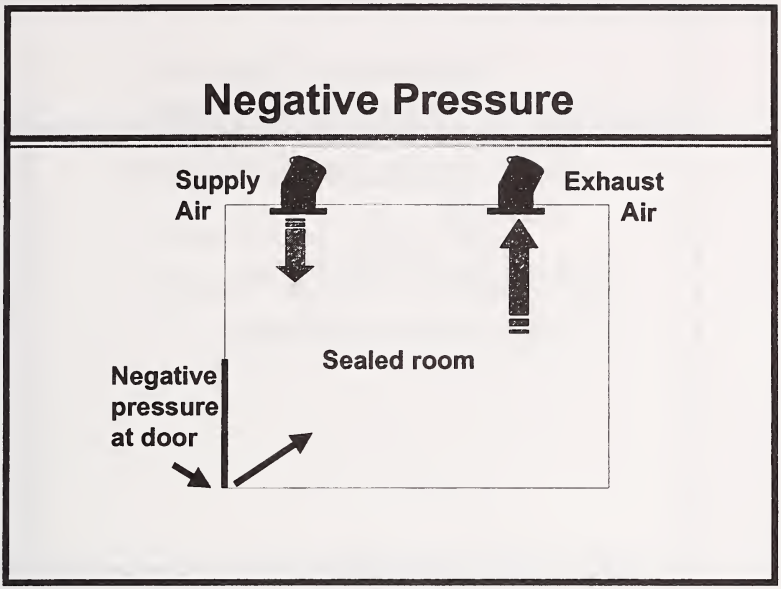


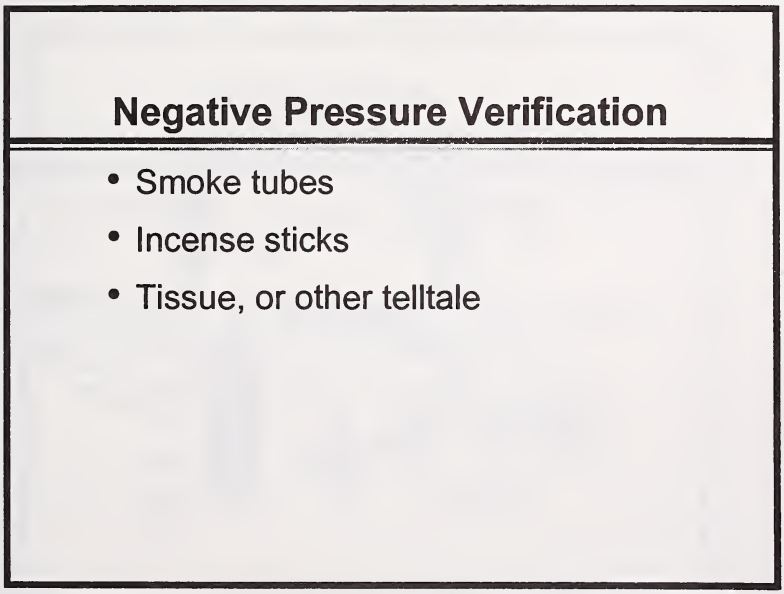
HEPA Filter Units

- Check for proper placement
- Read HEPA filter unit manual
- Change prefilters every 6 months*
- Change HEPA filters every 1 to 2 years
- Service and dispose of filters in accordance with local requirements

* This is a general recommendation. In certain locations, prefilters may need to be replaced more frequently.

5. Negative Pressure Verification





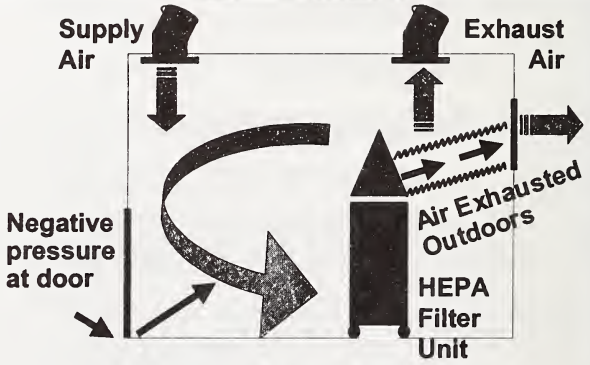
5. Negative Pressure Verification (continued)

Frequency of Negative Pressure Verification

- Daily when rooms are used for isolation
- Monthly, at other times
- Keep records of testing

6. Negative Pressure: How Much?

HEPA Unit for Negative Pressure



6. Negative Pressure: How Much? (continued)

Measuring Negative Pressure

- Pressure difference
- Speed of air under door
- Offset - excess exhaust airflow

7. Room Pressure Monitor

Room Pressure Monitor

- Measures pressure across a room boundary
- Compares measured pressure to the reference pressure value
- Test monitor monthly

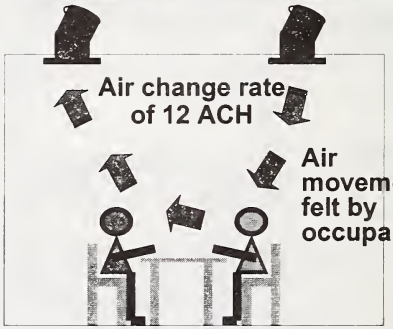
8. Room Clearance Time

Room Clearance Time Criteria

- Removal efficiency
- Ventilation rate, ACH
- Room air mixing

Room Clearance Time: The interval between the departure of an infectious TB patient from an isolation room or sputum induction room or booth, and the arrival of another person who is not wearing a respirator.

Increase Your Room Clearance Time



Assume a mixing factor of 3

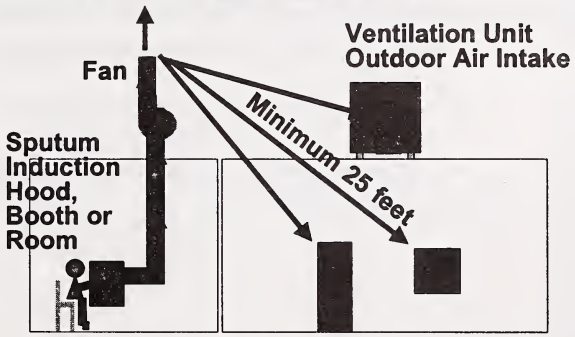
8. Room Clearance Time (continued)

Table S3-1. (page 72)

ACH	Minutes required for a removal efficiency of: 90%	99%	99.9%
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23 x 3 = 69 mins	
13	11	21	32
14	10	20	30

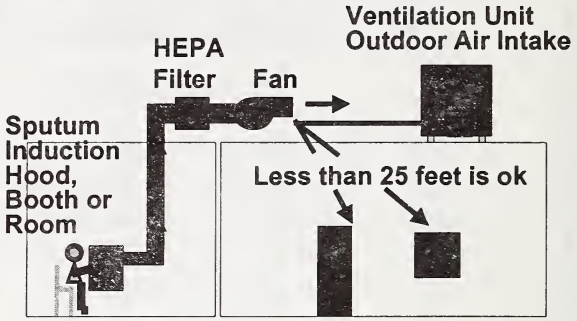
9. Sputum Induction

Exhaust from High Risk Areas



9. Sputum Induction (continued)

HEPA-Filtered Exhaust from High Risk Areas



Sputum Induction: Booth or Hood

- Minimum 200 FPM air velocity
- Avoid external air currents
- Safe exhaust or HEPA-filtered

9. Sputum Induction (continued)

Sputum Induction: No Booth or Hood

- Designated room that meets requirements for isolation rooms
- Verify negative pressure daily
- Enforce clearance time between patients

10. Waiting Rooms

Waiting Room Recommendations

- 10 ACH ventilation rate
- Direct exhaust to outdoors, or HEPA filtration
- Air should flow ***from*** staff area ***to*** waiting area

III. Guidelines, Tables, and Worksheets

Negative Pressure Isolation Rooms: Comparison of Regulations & Guidelines

	REGULATIONS		GUIDELINES		
	OSHPD[1]	**Cal/OSHA[2]**	**CDC[3]**	**ASHRAE[4]**	**AIA[5]**
Room designation	negative-pressure isolation room	atmospheric isolation	TB isolation rooms and treatment rooms	infectious isolation room	airborne infection isolation room
Applies to	new & remodel	all	all	new & remodel	new & remodel
Total air changes per hour (ACH)	>12	>12	prefer >12 minimum >6	6	>12
In-room HEPA recirculation allowed?	only for remodel under PIN 4, dated 2/16/96	yes	yes, if used to achieve 12 ACH	no	yes
Total ACH can include HEPA recirculation?	no	yes	yes	no	yes
HEPA filtered recirculation to other areas?	no	yes	only if unavoidable	no	yes
Dedicated exhaust required?	yes	no	no	no	no
Exhaust discharge location	on roof 25' from openings, and minimum 7' high or HEPA-filtered	sufficiently separated from fresh air intakes	to prevent reentry of air into building unless HEPA-filtered	on roof minimum 10' high, away from openings	on roof 25' from fresh air intakes

Negative Pressure Isolation Rooms: Comparison of Regulations & Guidelines

	REGULATIONS		GUIDELINES		
	OSHPD[1] Title 24	**Cal/OSHA[2] Title 8**	**CDC[3]**	**ASHRAE[4]**	**AIA[5]**
Minimum outside air change rate (OSA ACH)	2	not addressed	not addressed	2	2
Minimum exhaust air excess airflow	75 CFM	not addressed	10% of supply or 50 CFM, whichever is greater	not addressed	50 CFM
Minimum room pressure differential	0.001" W.G.	not addressed	0.001" W.G.	not addressed	not addressed
Minimum air velocity under door	100 FPM	not addressed	not addressed	not addressed	not addressed
Air distribution	supply high, exhaust low, specific arrangement	not addressed	see figure S3-2 on page 75 of CDC Guidelines	from clean (ceiling) to less clean (floor) areas	from clean (ceiling) to less clean (floor) areas
Upper-room or In-duct UVGI allowed?	not addressed	yes, but not in lieu of ventilation	yes, but not in lieu of ventilation	not addressed	yes, but not in lieu of ventilation
Variable air volume ventilation allowed	no	not addressed	not addressed	yes, but maintain minimum code ACH and pressurization	yes, but maintain minimum code ACH and pressurization

Negative Pressure Isolation Rooms: Comparison of Regulations & Guidelines

	REGULATIONS		GUIDELINES		
	OSHPD[1] Title 24	**Cal/OSHA[2] Title 8**	**CDC[3]**	**ASHRAE[4]**	**AIA[5]**
Minimum anteroom ACH	10	not addressed	not addressed	10	10
Minimum anteroom OSA ACH	2	not addressed	not addressed	2	no recommendation
Anteroom required?	yes	no	no	"may be desirable"	no
Anteroom pressurization?	positive to isolation room, neutral to corridor	not addressed	positive to isolation room, may vary to corridor	not addressed	positive to isolation room, negative to corridor
Monitoring of negative pressure	continuous, alarmed	test annually	check daily while being used for isolation	not addressed	

References

1. 1998 California Mechanical Code. Title 24, Part 4, Chapter 4: Ventilation Air Supply.
2. California Division of Occupational Safety and Health (Cal/OSHA). Interim Tuberculosis Control Enforcement Guidelines, revised 3/1/97. Policy and Procedure C-47.
3. Centers for Disease Control and Prevention. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. MMWR 1994;43(No. RR-13).
4. American Society of Heating, Refrigerating and Air Conditioning Engineers. Chapter 7: Health Care Facilities. In: 1999 HVAC Applications handbook. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1999.
5. American Institute of Architects, 1996-1997 Guidelines for Design and Construction of Hospitals and Health Care Facilities published by the American Institute of Architects Academy of Architecture for Health, with assistance from the Department of Health and Human Services (DHHS).

Air Changes Per Hour Calculation Sheet *(page 1 of 2)*

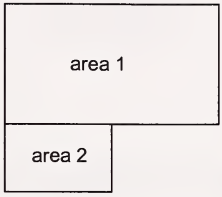
Building _____Floor _____Room #_____Room Name_____

A) Measurements

1) room dimensions

sketch of room with area references

for example



area reference	length	width	length X width = area
area 1			
area 2			
area 3			
area 4			
area 5			
total floor area =			

ceiling height = _____(feet)

2) airflow rates

measured exhaust airflow rate = _____CFM

measured supply airflow rate = _____cubic feet per minute (CFM)

Note: 1) Exhaust airflow rate must be greater than the supply airflow rate in negative pressure isolation or sputum induction rooms.

2) Airflow rates should be measured with a calibrated air flow rate meter (hood)

Air Changes Per Hour Calculation Sheet *(page 2 of 2)*

B) Calculations

Step 1: calculate room volume

room volume = total room floor area X ceiling height

= _____ ft^2 X _____ ft

= _____ ft^3

Step 2: calculate exhaust airflow rate

hourly exhaust airflow rate = Measured exhaust airflow rate in CFM X 60 minutes per hour

= _____CFM X 60 minutes per hour

= _____ ft^3 per hour

Step 3: calculate air changes per hour (ACH)

$$ACH = \frac{\text{exhaust air flow per hour (from step 2)}}{\text{room volume (from step 1)}}$$

$$= \frac{\text{\_\_\_\_\_ cubic feet per hour}}{\text{\_\_\_\_\_ } ft^3}$$

= _____ACH

Step 4: calculate additional CFM required

$$\text{total CFM required for desired ACH*} = \text{room volume} \times \frac{\text{desired ACH*}}{\text{60 minutes/hour}}$$

$$= \text{\_\_\_\_\_ } ft^3 \times \frac{\text{\_\_\_\_\_ ACH}}{\text{60 minutes/hour}}$$

= _____CFM

additional CFM = Total CFM required for desired ACH* - measured CFM

= _____CFM (required) - _____CFM (measured)

= _____CFM

* 12 ACH is recommended in isolation and sputum induction rooms and 10 ACH in waiting rooms.

Air Changes Per Hour Calculation Sheet *(page 1 of 2)* ** SAMPLE **

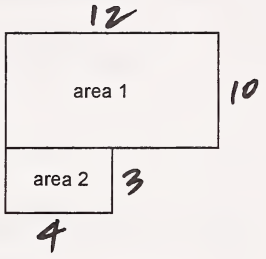
Building ____ | ____ Floor 2 Room # 123 Room Name Isolation 1

A) Measurements

1) room dimensions

sketch of room with area references

for example



area reference	length	width	length X width = area
area 1	12	10	120
area 2	3	4	12
area 3			
area 4			
area 5			
total floor area =			132

ceiling height = 9 1/2 **(feet)**

2) airflow rates

measured exhaust airflow rate = 170 CFM

measured supply airflow rate = 150 cubic feet per minute (CFM)

Note: 1) Exhaust airflow rate must be greater than the supply airflow rate in negative pressure isolation or sputum induction rooms.

2) Airflow rates should be measured with a calibrated air flow rate meter (hood)

Air Changes Per Hour Calculation Sheet *(page 2 of 2)* **** SAMPLE ****

B) Calculations

Step 1: calculate room volume

room volume = total room floor area X ceiling height

= 132 ft^2 X 9 1/2 ft

= 1,254 ft^3

Step 2: calculate exhaust airflow rate

hourly exhaust airflow rate = Measured exhaust airflow rate in CFM X 60 minutes per hour

= 170 CFM X 60 minutes per hour

= 10,200 ft^3 per hour

Step 3: calculate air changes per hour (ACH)

$$ACH = \frac{\text{exhaust air flow per hour (from step 2)}}{\text{room volume (from step 1)}}$$

$$= \frac{10,200 \text{ cubic feet per hour}}{1,254 \ ft^3}$$

= 8 ACH

Step 4: calculate additional CFM required

$$\text{total CFM required for desired ACH*} = \text{room volume} \times \frac{\text{desired ACH*}}{\text{60 minutes/hour}}$$

$$= 1,254 \ ft^3 \times \frac{12 \text{ ACH}}{\text{60 minutes/hour}}$$

= 250 CFM

additional CFM = Total CFM required for desired ACH* - measured CFM

= 250 CFM (required) - 170 CFM (measured)

= 80 CFM

* 12 ACH is recommended in isolation and sputum induction rooms and 10 ACH in waiting rooms.

NEGATIVE PRESSURE VERIFICATION SHEET

Negative pressure isolation rooms should be checked monthly at a minimum and daily when used as a negative pressure isolation room.
Sputum induction rooms should have negative pressure checked before each day's procedures.

BUILDING	ROOM #	ROOM NAME	AIRFLOW			PRESSURE READING IN INCHES OF WATER COLUMN (in.W.C.)	REMARKS
			VERIFICATION METHOD	INTO ROOM (-)	OUT OF ROOM (+)		

TABLE S3-1. Air changes per hour (ACH) and time in minutes required for removal efficiencies of 90%, 99%, and 99.9% of airborne contaminants*

ACH	Minutes required for a removal efficiency of:		
	90%	99%	99.9%
1	138	276	414
2	69	138	207
3	46	92	138
4	35	69	104
5	28	55	83
6	23	46	69
7	20	39	59
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23	35
13	11	21	32
14	10	20	30
15	9	18	28
16	9	17	26
17	8	16	24
18	8	15	23
19	7	15	22
20	7	14	21
25	6	11	17
30	5	9	14
35	4	8	12
40	3	7	10
45	3	6	9
50	3	6	8

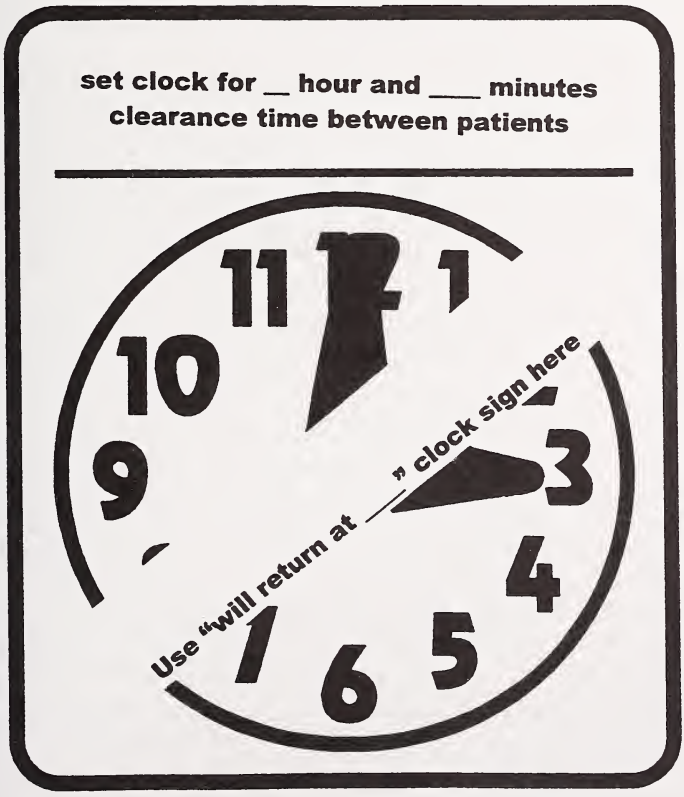
*This table has been adapted from the formula for the rate of purging airborne contaminants (*99*). Values have been derived from the formula $t_1 = [\ln (C_2 \div C_1) \div (Q \div V)] \times 60$, with $T_1 = 0$ and $C_2 \div C_1$ – (removal efficiency ÷ 100), and where:

t_1 = initial timepoint
C_1 = initial concentration of contaminant
C_2 = final concentration of contaminants
Q = air flow rate (cubic feet per hour)
V = room volume (cubic feet)
$Q \div V$ = ACH

The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur, and the mixing factor could be as high as 10 if air distribution is very poor (*98*). The required time is derived by multiplying the appropriate time from the table by the mixing factor that has been determined for the booth or room. The factor and required time should be included in the operating instructions provided by the manufacturer of the booth or enclosure, and these instructions should be followed.

Clearance Room Signage Sample

N-95 RESPIRATOR MUST BE WORN WHEN ENTERING THIS ROOM UNTIL



IV. Additional Resources

Glossary

ACH: Air changes per hour. This is a measurement commonly used to express the ventilation rate of a space. ACH is the number of times an amount of air equal to the volume of the space is exhausted or supplied every hour.

CFM: Cubic feet per minute. This is a measurement commonly used to express an airflow quantity. Airflow hoods usually provide readouts in CFM.

diffuser: Mechanical device that supplies air to a space. Diffusers are usually at the ceiling, but can be on the wall.

exhaust air: Air that is removed from a building by a fan system, as opposed to air that is removed from a space and then recirculated or returned.

grille: Mechanical device that removes exhaust or return air from a room. Grilles are usually on the ceiling but can be on the wall. For a negative pressure isolation room, the optimum location for the grille is low on the wall near the head of the bed.

HEPA filter: High efficiency particulate air filter. This is a filter that removes all particles in the size range of TB droplet nuclei.

HEPA filter unit: Self-contained machine consisting mainly of a HEPA filter, a prefilter, and a fan. These units can be used to provide clean air to supplement a building ventilation system.

mixing factor: Safety factor used when calculating room clearance times to compensate for imperfect air mixing.

return air: Air that is removed from a space by a mechanical system but not all discharged directly outdoors. This air is usually returned to the mechanical system where a portion of it is exhausted. The remainder is diluted with some outdoor air, filtered, conditioned (or heated) and then distributed.

removal efficiency: Percentage of airborne particles removed from an isolation room or sputum induction room or booth.

Glossary

room clearance time: The interval between the departure of an infectious TB patient from an isolation room or sputum induction room or booth, and the arrival of another person who is not wearing a respirator.

supply air: Air that is introduced into a space by a mechanical system.

ventilation rate: Quantity of air that is removed or supplied from a room. It is usually expressed in air changes per hour (ACH).

Web Resources

http://www.cdc.gov/niosh/homepage.html
National Institute of Occupational Safety and Health - CDC

http://www.osha-slc.gov/SLTC/tuberculosis/index.html
Occupational Safety and Health Administration – TB information

http://www.cdc.gov/nchstp/tb/default.htm
Division of TB Elimination, National Center for STD, HIV and TB Prevention - CDC

http://www.cdc.gov/ncidod/ncid.htm
National Center for Infectious Diseases – CDC

http://members.aol.com/tbidc/Index.html
Princeton Project 55 Inc. – Tuberculosis Initiative

http://www.who.ch/gtb/
World Health Organization – Global TB Programme

http://www.nationaltbcenter.edu
Francis J. Curry National Tuberculosis Center

V. Evaluation Form

How You Can Assess Engineering Controls for TB in Your Healthcare Facility

You Don't Need a Weatherman to Know Which Way the Wind Blows

EVALUATION FORM

Your feedback about this video is very important to us and will help us to design future distance learning programs. Please complete this evaluation form and fax to **(415) 502-7561** or mail it to:

Distance Learning Projects
Francis J. Curry National Tuberculosis Center
3180 18th Street, Suite 101
San Francisco, CA 94110-2028

As an expression of our appreciation for your feedback, when we receive your completed evaluation form, we will send you a packet of recent journal articles about TB. Please be sure to include your name and address at the end of the page 2. Thank you!

	Excellent	Good	Average	Fair	Poor	Comments
1. Overall, how would you rate this video?	5	4	3	2	1	
2. How would you rate the viewer's guide?	5	4	3	2	1	

	Strongly Agree				Strongly Disagree	Comments
3. I learned something new that was important.	5	4	3	2	1	
4. I plan to discuss this information with colleagues.	5	4	3	2	1	
5. I plan to seek more information about engineering controls.	5	4	3	2	1	
6. I plan to make changes in my facility based on issues featured in this video.	5	4	3	2	1	
7. I would recommend this video to a colleague.	5	4	3	2	1	
8. Video was an effective way to learn this material.	5	4	3	2	1	

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9. Specifically, what did you like about the video?

10. What did you not like about it? How would you improve it?

(continued on next page)

11. What will you do differently in your work as a result of viewing this video?

12. Please comment on the content of the video.

Help us plan future distance learning programs by answering the following...

13. Did you view this video… a. ☐ at work b. ☐ at home c. ☐ both

14. Did you view this video… a. ☐ alone b. ☐ with one other person c. ☐ with 2 or more people

15. Do you have access to a computer with a connection to the Internet? a. ☐ Yes b. ☐ No

Tell us about yourself...

16. What is your principal occupation? *(please check only one)*

a. ☐ Infection control practitioner b. ☐ Engineer

c. ☐ Employee health practitioner d. ☐ Other _____

17. Which of the following most closely describes your work setting?

	Public	Private
Acute care hospital	a. ☐	b. ☐
Public health or infectious disease clinic	c. ☐	d. ☐
Primary care, general medicine or family practice setting	e. ☐	f. ☐

Other (please specify): g. _____

18. What percent of your job is devoted to TB? _____%

Thank you for taking the time to share your feedback!

To receive your packet of articles about TB, please complete the following section:

Last name _____ First name _____ MI_____

Position title _____ Degree(s) used after name _____

Organization _____ Division _____

Mailing address _____ City _____

State _____ Zip Code _____ Country _____

Daytime telephone: (_____) _____ Extension _____ Fax (_____) _____

E-mail: